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CHAPTER II

DEMAND

under Article 31 of the Patent Cooperation Treaty:

The undersigned requests that the international application specified below be the subject of international preliminary examination according to the Patent Cooperation Treaty and hereby elects all eligible States (except where otherwise indicated).

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Identification of IPEA	Date of receipt of DEMAND
Box No. I IDENTIFICATION OF THE INTERNATIONAL APPLICATION Applicant's or agent's file reference 40137588	
International application No. PCT/AU99/00785	International filing date (day/month/year) 16 September 1999 16/09/99
(Earliest) Priority date (day/month/year) 28 September 1998 28/09/98	
Title of invention SOIL REMEDIATION SYSTEM	
Box No. II APPLICANT(S)	
Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.) INNOVA SOIL TECHNOLOGY PTY LTD 3 Buchanan Street Hamilton, New South Wales 2303 AUSTRALIA	
Telephone No.:	
Facsimile No.:	
Teleprinter No.:	
State (that is, country) of nationality: AUSTRALIA	State (that is, country) of residence: AUSTRALIA
Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.) LUCAS, John, Anthony 3 Buchanan Street Hamilton, New South Wales 2303 AUSTRALIA	
State (that is, country) of nationality: AUSTRALIA	
State (that is, country) of residence: AUSTRALIA	
Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.) WIBBERLEY, Louis, James 5A Park Road Garden Suburb, New South Wales 2289 AUSTRALIA	
State (that is, country) of nationality: GREAT BRITAIN	
State (that is, country) of residence: AUSTRALIA	
<input type="checkbox"/> Further applicants are indicated on a continuation sheet.	

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The following person is ☒ agent ☐ common representative
 and ☒ has been appointed earlier and represents the applicant(s) also for international preliminary examination.
☐ is hereby appointed and any earlier appointment of (an) agent(s)/common representative is hereby revoked.
☐ is hereby appointed, specifically for the procedure before the International Preliminary Examining Authority, in addition to the agent(s)/common representative appointed earlier.

Name and address: (Family name followed by given name; for a legal entity, full official designation.
The address must include postal code and name of country.)

NOONAN, Greg
 CHERRY, James
 DI GIANTOMASSO, Frank
 CALLINAN, Keith
 JONES, Paul
 DAVY, John
 TULLOCH, Debra

Freehills Patent Attorneys
 Level 47
 101 Collins Street
 Melbourne, Victoria 3000
 AUSTRALIA

Telephone No.:

(613) 9288 1577

Facsimile No.:

(613) 9288 1567

Teleprinter No.:

☐ Address for correspondence: Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.

Box No. IV BASIS FOR INTERNATIONAL PRELIMINARY EXAMINATION**Statement concerning amendments:***

1. The applicant wishes the international preliminary examination to start on the basis of:

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- the description ☐ as originally filed
☐ as amended under Article 34
- the claims ☐ as originally filed
☐ as amended under Article 19 (together with any accompanying statement)
☐ as amended under Article 34
- the drawings ☐ as originally filed
☐ as amended under Article 34

2. ☐ The applicant wishes any amendment to the claims under Article 19 to be considered as reversed.

3. ☐ The applicant wishes the start of the international preliminary examination to be postponed until the expiration of 20 months from the priority date unless the International Preliminary Examining Authority receives a copy of any amendments made under Article 19 or a notice from the applicant that he does not wish to make such amendments (Rule 69.1(d)). (This check-box may be marked only where the time limit under Article 19 has not yet expired.)

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Language for the purposes of international preliminary examination: ENGLISH

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☐ which is the language of publication of the international application.
☐ which is the language of the translation (to be) furnished for the purposes of international preliminary application.

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The demand is accompanied by the following elements, in the language referred to in Box No. IV, for the purposes of international preliminary examination:

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| 2. | amendments under Article 34 | : | sheets |
| 3. | copy (or, where required, translation) of amendments under Article 19 | : | sheets |
| 4. | copy (or, where required, translation) of statement under Article 19 | : | sheets |
| 5. | letter | : | sheets |
| 6. | other (<i>specify</i>) | : | sheets |

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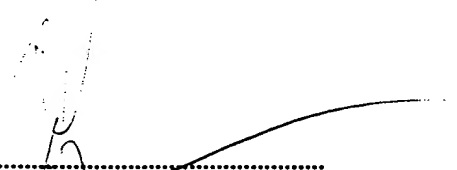
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Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the demand).



Greg Noonan, authorised agent
for and on behalf of the applicants

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- | | | |
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NOTIFICATION OF THE RECORDING
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From the INTERNATIONAL BUREAU

To:

NOONAN, Greg
Freehills Patent Attorneys
Level 47
101 Collins Street
Melbourne, VIC 3000
AUSTRALIE

Date of mailing (day/month/year)

18 May 2000 (18.05.00)

Applicant's or agent's file reference

40137588

IMPORTANT NOTIFICATION

International application No.

PCT/AU99/00785

International filing date (day/month/year)

16 September 1999 (16.09.99)

1. The following indications appeared on record concerning:



the applicant



the inventor



the agent



the common representative

Name and Address

INNOVA SOIL TECHNOLOGY PTY. LTD.
76 Dumaresq Street
Hamilton South
Newcastle, NSW 2303
Australia

State of Nationality

AU

State of Residence

AU

Telephone No.

Facsimile No.

Teleprinter No.

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:



the person



the name



the address



the nationality



the residence

Name and Address

INNOVA SOIL TECHNOLOGY PTY. LTD.
3 Buchanan Street
Hamilton, NSW 2303
Australia

State of Nationality

AU

State of Residence

AU

Telephone No.

Facsimile No.

Teleprinter No.

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The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No.: (41-22) 740.14.35

Authorized officer

A. Karkachi

Telephone No.: (41-22) 338.83.38

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NOTIFICATION OF THE RECORDING
OF A CHANGE(PCT Rule 92bis.1 and
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From the INTERNATIONAL BUREAU

To:

NOONAN, Greg
Freehills Patent Attorneys
Level 47
101 Collins Street
Melbourne, VIC 3000
AUSTRALIE

Date of mailing (day/month/year) 18 May 2000 (18.05.00)	IMPORTANT NOTIFICATION
Applicant's or agent's file reference 40137588	
International application No. PCT/AU99/00785	
International filing date (day/month/year) 16 September 1999 (16.09.99)	

1. The following indications appeared on record concerning:		
<input checked="" type="checkbox"/> the applicant	<input checked="" type="checkbox"/> the inventor	<input type="checkbox"/> the agent <input type="checkbox"/> the common representative
Name and Address LUCAS, John, Anthony 76 Dumaesq Street Hamilton South Newcastle, NSW 2303 Australia	State of Nationality AU	State of Residence AU
	Telephone No.	
	Facsimile No.	
	Teleprinter No.	
2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:		
<input type="checkbox"/> the person	<input type="checkbox"/> the name	<input checked="" type="checkbox"/> the address <input type="checkbox"/> the nationality <input type="checkbox"/> the residence
Name and Address LUCAS, John, Anthony 3 Buchanan Street Hamilton, NSW 2303 Australia	State of Nationality AU	State of Residence AU
	Telephone No.	
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3. Further observations, if necessary:		
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The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland Facsimile No.: (41-22) 740.14.35	Authorized officer A. Karkachi Telephone No.: (41-22) 338.83.38
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PCT COOPERATION TREATY

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To:

NOONAN, Greg
Freehills Carter Smith & Beadle
101 Collins Street
Melbourne, VIC 3000
AUSTRALIE

Date of mailing (day/month/year) 15 June 2000 (15.06.00)	IMPORTANT NOTIFICATION
Applicant's or agent's file reference 40137588	
International application No. PCT/AU99/00785	International filing date (day/month/year) 16 September 1999 (16.09.99)

1. The following indications appeared on record concerning:

☐ the applicant ☐ the inventor ☒ the agent ☐ the common representative

Name and Address

NOONAN, Greg
Freehills Patent Attorneys
Level 47
101 Collins Street
Melbourne, VIC 3000
Australia

State of Nationality

State of Residence

Telephone No.

03 9288 1577

Facsimile No.

03 9288 1567

Teleprinter No.

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

☐ the person ☐ the name ☒ the address ☐ the nationality ☐ the residence

Name and Address

NOONAN, Greg
Freehills Carter Smith & Beadle
101 Collins Street
Melbourne, VIC 3000
Australia

State of Nationality

State of Residence

Telephone No.

03 9288 1577

Facsimile No.

03 9288 1567

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3. Further observations, if necessary:

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34, chemin des Colombettes
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Authorized officer

R. Raissi

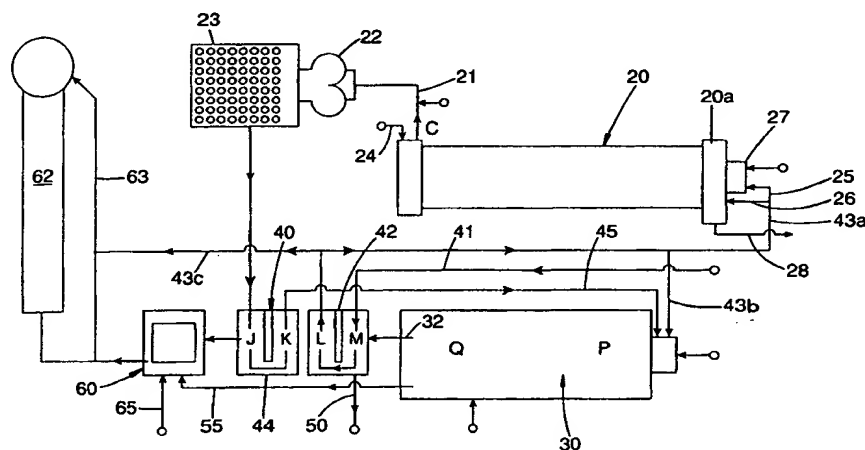
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(22) International Filing Date: 16 September 1999 (16.09.99)		
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(71) Applicant (for all designated States except US): INNOVA SOIL TECHNOLOGY PTY. LTD. [AU/AU]; 76 Dumaresq Street, Hamilton South, Newcastle, NSW 2303 (AU).		
(72) Inventors; and (75) Inventors/Applicants (for US only): LUCAS, John, Anthony [AU/AU]; 76 Dumaresq Street, Hamilton South, Newcastle, NSW 2303 (AU). WIBBERLEY, Louis, James [GB/AU]; 5A Park Road, Garden Suburb, NSW 2289 (AU).		
(74) Agents: NOONAN, Greg et al.; Freehills Patent Attorneys, Level 47, 101 Collins Street, Melbourne, VIC 3000 (AU).		Published <i>With international search report.</i>

(54) Title: SOIL REMEDIATION SYSTEM



(57) Abstract

A process for energy efficient remediation of soil contaminated with hydrocarbons, including desorbing the hydrocarbon contaminants from a bed of the soil by thermal desorption in a treated desorption chamber (20) and thereafter combusting the contaminants in a thermal oxidiser (30). The combustion air for the desorption chamber and the thermal oxidiser, and the desorbed contaminants prior to admission to said thermal oxidiser, are preheated by heat exchange (40) with offgases from the thermal oxidiser. An apparatus is also disclosed, as are processes in which the separated contaminants are treated in the thermal oxidiser in at least two stages, including a combustion stage (P) in which the contaminants are combusted with a first supply of combustion air at a substantially adiabatic temperature in the range 900–1200 °C, and a second stage (a) in which a second supply of combustion air is admitted for combustion of residual compounds and for controlling the offgas outflow temperature, and a process in which the desorbed contaminants in gaseous form are at least in part combusted within the desorption chamber by controlled admission of air into the chamber above the bed to effect such combustion.

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SOIL REMEDIATION SYSTEM

Field of the Invention

The present invention relates to the remediation of soil contaminated with hydrocarbons, utilising thermal desorption followed by thermal oxidation.

5 Background Art

There are numerous other types of processes for remediating soils, including soil washing, in-situ air stripping, in-situ vitrification, stabilisation, vacuum extraction and solvent extraction. However, the most universally proven and efficient method for removing organics from soil is thermal desorption, which
10 together with treatment or destruction of the desorbed organics is termed thermal remediation. Hydrocarbon contaminants which are treatable with thermal remediation include:

- Volatile organic compounds (VOC) eg petrol, diesel,
- Aromatic hydrocarbons eg benzene, tars,
- 15 • Dioxins and furans,
- Semi-volatile organic compounds (SVOCs),
- Polynuclear aromatic hydrocarbons (PAHs or PNAs),
- Polychlorinated biphenyls (PCBs), and
- Pesticides (eg organochlorins such as dieldrin and aldrin).

20 Thermal remediation of contaminated soil uses heat to physically separate hydrocarbon based contaminants from feed material which may be, for example, directly recovered soils, sediments, sludges or filter cakes. The separated hydrocarbons are then combusted or thermally oxidised to produce essentially carbon dioxide and water vapour.

25 The most common process configuration involves a counter-current direct

fired desorber, but there are numerous variants. The most common alternative is the co-current desorber, which produces a hotter contaminated offgas stream. To avoid cooling these gases to enable fabric filtration, a cyclone is used to remove some of the dust prior to thermal oxidation, followed by gas cooling then fabric
5 filtration. In another variant the functions of the thermal desorber and oxidiser are combined by arranging to combust the contaminant gases within a metal jacketed combustion chamber within a rotary desorber.

United States patent 5658094 discloses an arrangement in which heat exchangers are used for preheating combustion air for a thermal desorber. In that
10 arrangement, there is described a combined (all metal) rotary device, a type of rotary kiln with internal indirect heating of both soil and combustion air, which is claimed to carry out combined thermal desorption and thermal oxidation.

German patent application 3447079 describes a process in which the contaminated soil is thermally treated in a rotary kiln by the direct addition of hot
15 combustion gases and/or air. The decomposition products are partially combusted in the rotary kiln, with the remaining production gas fed to a waste gas combustion chamber where it is afterburnt at high temperatures. In general, the post-combustion waste gases are cooled and released into the atmosphere.

Various other methods of thermal remediation of soil are described in
20 United States patents 5,455,005, 5,393,501, 4,715,965, 4,974,528, and 5,378,083.

The main difference between different technologies is the equipment used for thermal desorption, which may be one of four main types, the advantages and disadvantages of which are summarised in Table 1 (obtained from various
25 sources, including W.L. Troxler et al, "Treatment of non-hazardous petroleum-contaminated soils by thermal desorption technologies", Jnl of Air and Waste, Vol. 43, Nov. 1993, and W.C. Anderson, "Innovative site remediation technology", Thermal Desorption, WASTECH, 1993).

Table 1

Main Types of Thermal Remediation

	Advantages	Disadvantages
Direct fired rotary kilns	<ul style="list-style-type: none"> • High rates of heat transfer. • Smaller desorber than indirect fired. • Simplest, most robust. • Most flexible to variation in feed material and type and level of contamination. 	<ul style="list-style-type: none"> • Larger thermal oxidiser than for indirect fired. • Dilution strategies are usually required for hydrocarbon contamination levels of >4% to avoid exceeding the LEL of desorber offgases.
Indirect fired rotary kilns	<ul style="list-style-type: none"> • May allow economic recovery of hydrocarbons. • Lower dust losses from desorber. 	<ul style="list-style-type: none"> • Unsuitable for heavy contamination, especially of long chain or aromatic hydrocarbons (tars). • Larger desorber. • Higher moisture soils severely impair capacity.
Combination direct/indirect fired desorber, with integral thermal oxidiser	<ul style="list-style-type: none"> • Process simplification by using a single process step. 	<ul style="list-style-type: none"> • Inability to process large gas volumes. • Lower peak soil temperatures will prevent practical decontamination of heavily contaminated soils, especially with PAHs or PCBs. • Less suitable for high moisture soils.
Direct fired conveyors, including metal belts and screws	<ul style="list-style-type: none"> • As for indirect fired rotary kilns. • Improved control over solids residence time. 	<ul style="list-style-type: none"> • As for indirect fired rotary kilns.
Direct fired fluidised beds	<ul style="list-style-type: none"> • Highest process intensity. 	<ul style="list-style-type: none"> • Increased complexity. • Increased dust losses/recycling of dusts. • Requires fine and uniform sized material (normally less than 5mm). • Increased maintenance (abrasion).

Remediation plants may be either stationary or mobile, with the larger, stationary plants being restricted to remediation of large heavily contaminated sites (eg large integrated steelworks sites), regional clusters of contaminated sites, or under circumstances where transport of contaminated materials is economic
5 and not hazardous.

Key technical factors in thermal remediation include:

- Solids temperature and contact time.
- Soil moisture when treated.
- Actual soil hydrocarbon contaminants present.
- 10 • Other contamination, eg chlorine compounds and heavy metals.
- Extraneous rubble.

It is an object of the present invention to provide an improved method and apparatus for remediating soil contaminated with hydrocarbons that is capable in preferred embodiment of optimising energy usage and operating costs for a given
15 soil throughput, and that is preferably adaptable to treat short chain, long chain, aromatic, and polychlorinated hydrocarbons. In particular embodiments, it is further desired to minimise environmental impacts, especially greenhouse gases, NO_x and dioxin/furan emissions.

Summary of Invention

20 The invention accordingly provides, in a first aspect, a process for remediating soil contaminated with hydrocarbons, including:

desorbing the hydrocarbon contaminants from a bed of the soil by thermal desorption in a treated desorption chamber and thereafter combusting the contaminants in a thermal oxidiser,

25 wherein desorbed contaminants in gaseous form are at least in part combusted within said desorption chamber by controlled admission of air

into said chamber above said bed to effect such combustion.

In its first aspect, the invention further provides apparatus for remediating soil contaminated with hydrocarbons, including:

5 first furnace means defining a desorption chamber in which a bed of said soil may be treated to separate the hydrocarbon contaminants from the soil by thermal desorption;

second furnace means for combusting hydrocarbon contaminants by thermal oxidation;

10 means for controlled admission of air into said desorption chamber above said bed to effect in the said chamber at least partial combustion of said desorbed contaminants in gaseous form; and

means for conveying the products of said at least partial combustion to said second furnace means for further combustion therein.

15 Preferably, the desorption chamber is provided in a rotary kiln that thereby constitutes the first furnace means and is preferably inclined. The contaminated soil, which is advantageously optimally sized and prepared, is preferably admitted to an upper, cooler end of the rotary kiln at a controlled rate, and the rotation of the kiln then causes the soil to move down the inside of the kiln towards the hotter end containing a burner. The heat from the burner and other exothermic reactions
20 in the kiln heats the soil, causing it to dry and "desorb" (a term which includes without limitation evaporation, decomposition and gasification) contained hydrocarbon contaminants.

25 Preferably, the at least partial combustion of the contaminants in the desorption chamber occurs both in close proximity to the soil bed and in the hot gas stream passing along the desorber. The air admitted to effect such combustion may be injected at the burner end of the desorption chamber. The first furnace means is preferably a high velocity desorber burner which provides a

highly collimated stream of high temperature gases along the centre of the desorber.

In a second aspect, the invention provides a process for remediating soil contaminated with hydrocarbons, including:

5 desorbing the hydrocarbon contaminants from a bed of the soil by thermal desorption in a treated desorption chamber and thereafter combusting the contaminants in a thermal oxidiser;

wherein combustion air for said desorption chamber and said thermal oxidiser, and said desorbed contaminants prior to admission to said thermal
10 oxidiser, are preheated by heat exchange with offgases from the thermal oxidiser.

The invention further provides, in its second aspect, apparatus for remediating soil contaminated with hydrocarbons, including:

15 first furnace means defining a desorption chamber in which a bed of said soil may be treated to separate the hydrocarbon contaminants from the soil by thermal desorption;

second furnace means for combusting hydrocarbon contaminants by thermal oxidation;

20 means for conveying combustion air to said desorption chamber and to said second furnace means, and for conveying the desorbed contaminants from the absorption chamber to the second furnace means; and

heat exchange means arranged for preheating said combustion air and said desorbed contaminants by heat exchange with offgases from the second furnace means.

25 Preferably, the heat exchange means is further arranged in a series

configuration so that said offgases preheat the combustion air first and then the desorbed contaminants.

Advantageously, the heat exchange means is directly installed in the hot gas duct at the offgas outlet end of the second furnace means for thermal oxidation, and is preferably arranged for co-current flow. The leading tube bank of the heat exchange means preferably incorporates variable tube spacing to facilitate the aforementioned direct installation (preferably without radiation shields or excess metal temperatures).

There may be an energy dump valve from the heat exchange means for venting of excess preheated air as will occur during treatment of higher contaminated soil. Preferably, the process and energy dump valve are controlled to maintain metal temperatures above 500°C, to minimise dioxin formation from PCB or salt contaminated soils, but below 700°C to minimise metal oxidation, corrosion and expansion damage. The heat exchange means may have a hot gas by-pass duct and damper system in either or both the offgas duct or by-pass duct to control hot gas flow through both the combustion air and contaminants heat exchanges.

The heat exchanger for the contaminants may have either co-current or counter current flow, and may be adapted to be made reversible depending on operating conditions.

In a third aspect, the invention provides a process for remediating soil contaminated with hydrocarbons, including:

desorbing the hydrocarbon contaminants from a bed of the soil by thermal desorption in a treated desorption chamber and thereafter combusting the contaminants in a thermal oxidiser;

wherein the separated contaminants are treated in said thermal oxidiser in at least two stages, including a combustion stage in which the contaminants are combusted with a first supply of combustion air at a substantially

adiabatic temperature in the range 900 - 1200°C, and a second stage in which a second supply of combustion air is admitted for combustion of residual compounds and for controlling the offgas outflow temperature.

The invention also provides, in this third aspect, apparatus for remediating
5 soil contaminated with hydrocarbons, including:

first furnace means defining a desorption chamber in which a bed of said soil may be treated to separate the hydrocarbon contaminants from the soil by thermal desorption;

10 second furnace means for combusting hydrocarbon contaminants by thermal oxidation;

wherein said second furnace for thermal oxidation includes at least two stages including a combustion stage in which the contaminants are combusted with a first supply of combustion air at a substantially adiabatic temperature in the range 900 - 1200°C, and a second stage in which a
15 second supply of combustion air is admitted for combustion of residual compounds and for controlling the offgas outflow temperature.

In the preferred operation of the first stage of the thermal oxidiser, preheated near stoichiometric amounts of combustion air, preheated dedusted desorber offgases, ie desorbed contaminants, and auxiliary fuel are injected,
20 preferably via a nozzle mix burner. The fuel rate and preheat to this burner is arranged to give said adiabatic flame temperature of the mixture of 900-1200°C, and thus avoids localised high temperatures and high NO_x from the use of preheated combustion air. However, the temperature is sufficient to destroy any gaseous contaminants in the desorber gases. These hot gases then pass into the
25 second zone of the thermal oxidiser where cold or preheated combustion air is injected into the hot gas stream to provide additional mixing and oxygen for combustion of residual compounds, and to control the gas inlet temperature to the heat exchangers.

The invention also extends to methods or apparatus incorporating two or more of the three disclosed aspects of the invention.

The offgas from thermal oxidation may be further treated (eg after said heat exchanges in the second aspect of the invention) by one or more modular off-gas treatments according to the nature of the original contaminants, and the requirements of the soils being remediated. For low chlorine containing soils, such an off-gas treatment system may be omitted, and replaced with a short stack. For higher chlorine containing soils, where the risk of dioxin or hydrochloride containing gases is evident, a scrubber section may be used. A suitable scrubber can treat most of the offgases. A small bleed of hot off-gas or preheated combustion air is allowed to by-pass the scrubber to provide reheating of the scrubbed gas stream in the stack thereby preventing drooping or visible plumes. For gases of intermediate chlorine compound content, a module comprising an ambient air quenching module may be used, wherein a large volume of ambient air is injected into the offgases to rapidly quench them to less than 200°C.

Brief Description of the Drawings

Figure 1 is a block flow diagram of an apparatus incorporating embodiments of all three principal aspects of the invention; and

Figure 2 is a diagram depicting combustion of desorbed contaminants in the desorber kiln.

Description of Preferred Embodiments

The illustrated system includes a pair of furnaces 20, 30, being a slightly inclined countercurrent rotary kiln 20 for effecting thermal desorption and a 2-stage thermal oxidiser 30. The off-gases 32 from thermal oxidiser 30 pass directly through a 2-stage heat exchanger 40. In the first stage 42 of the series arrangement, itself consisting of a pair of sub-stage tube banks M, L, cold combustion air admitted along supply duct 41 is pre-heated for delivery to the lower, burner ends of desorber kiln 20 and oxidiser 30 by respective combustion

air ducts 43a, 43b. In the second stage 44 of heat exchanger 40, again consisting of respective sub-stage tube banks J, K, off-gases (including desorbed contaminants) recovered from the upper end of desorber kiln 20 via line 21, and cleaned and dedusted by cyclone 22 and bagfilter 23, are pre-heated for delivery
5 to the burner end of thermal oxidiser 30 via contaminant vapours supply line 45. Preheating may be to a temperature in the range 350-500°C.

Sized and otherwise prepared soils requiring remediation are transferred at a controlled rate into the upper or cooler end of desorber kiln 20 at delivery port 24. The desorber kiln is inclined so that its rotation causes the soil to move down
10 inside the kiln towards the burner end 20a. The heat from the burner 27 and from other exothermic reactions in the kiln, heats the soil, causing it to dry and desorb contained hydrocarbon contaminants.

The pre-heated combustion air in delivery duct 43a for desorber kiln 20 is divided into a first stream 25 for burner 27, and a second stream 26 of overbed
15 combustion air for effecting at least partial combustion of the desorbed hydrocarbon contaminants within the kiln. This combustion takes place both in close proximity to the soil bed in the kiln and to the soil particles cascading through the hot gas stream, and in the hot gas stream passing along its interior. A suitable kiln for the desorber 20 is a high velocity burner such as the North
20 American Hi Ram kiln burner, which provides a highly collimated stream of high temperature gases along the centre of the kiln. Application of this burner type with the abovementioned admission of overbed air 26 ensures efficient and reliable ignition of hydrocarbons as they evolve from the soil as it progresses along the kiln, as depicted in Figure 2.

25 In the case of soils with high hydrocarbon contamination levels, energy conservation will be secondary to controlling the level to be below the Lower Explosive Limited (LEL) (typically 1½ - 2%) of the desorber off-gas. For this situation, the temperature of the desorber off-gases in duct 21 may be increased by controlling both the energy input to the desorber burner 27 and the amount of
30 insitu combustion, to allow dilution of the desorber off-gases prior to gas cleaning. Controlled amounts of water may be injected via sprays 29 located in duct 21

immediately downstream of the desorber kiln. Thus as hydrocarbon contamination increases to a value above the LEL, combustion is controlled in the kiln both to minimise energy consumption and to keep the hydrocarbon level in the off-gas below the LEL: energy efficiency and safety issues must both be managed.

- 5 Remediated soil is recovered from desorber kiln at 28 at burner end 21a. The vapours exiting the desorber in duct 21 typically at around 275°C, typically comprise 50% steam, 5% carbon dioxide, 44% nitrogen, and approximately 0.5-1% volatile hydrocarbons contaminants desorbed from the soil bed. As previously mentioned these vapours are cleaned of solid matter entrained from the kiln by
10 cyclone 22 and/or bagfilter 23 before being pre-heated in heat exchanger stage 44 and injected into the thermal oxidiser via line 45.

The thermal oxidiser 30 is a 2-stage refractory-lined chamber comprising one or more burners to assist complete combustion of the hydrocarbon contaminated vapours from the thermal desorber. Typically the gases are heated
15 and combusted at 1000-1200°C for approximately 1000ms. To minimise NO_x formation, and to decrease radiation to the front of the heat exchanger, the thermal oxidiser has two sequential combustion zones; i) the primary combustion zone (P) and, ii) the post-combustion zone (Q). Preheated combustion air, preheated contaminant vapours and auxiliary fuel are injected into the primary
20 combustion zone using, preferably, but not restricted to, a nozzle mixing burner or burners 36. The air in the gas mixture is controlled to give an overall stoichiometric or slightly sub-stoichiometric combustion. Additional unheated combustion air is injected via ports around the periphery and at the entry to an afterburner 55 to give an overall excess oxygen in the hot gases of approximately
25 3% to ensure complete destruction of contaminant hydrocarbons, to provide additional turbulence, and to control the temperature of the gases entering the heat exchanger to typically between 950 and 1100°C. Gas temperatures above 1100°C will lead to decreased heat exchanger life.

Features of heat exchanger 40 include a wider tube spacing for the leading
30 rows of tubes (typically three rows, to decrease convective heat transfer to these rows subject to high radiant heat fluxes), in bank M, and an energy dump valve

50. The combination of these features allows direct installation of heat exchanger 40 in the hot gas duct at the outlet of thermal oxidiser 30, without the need for radiation shields and without incurring excess metal temperatures. This saves weight and cost. Dump valve 50 allows venting of excess pre-heated air from the leading tube bank M during operation. This dumping allows accurate control of the process energy balance with varying moisture and hydrocarbon contamination levels. In addition, this facility decreases manufacturing costs for the heat exchanger by allowing the use of lower alloy steels, and increases heat exchanger life.

10 An optional feature to cope with even more extreme and variable operating conditions is to equip heat exchanger 40 with a bypass duct 55 and associated damper (either in one or both of the heat exchanger stages), to further increase the flexibility of the process to treat higher contaminated soils, and to improve the operational safety of the heat exchanger stages.

15 The heat exchanger features, together with controlled combustion of hydrocarbon contaminants in desorber kiln 20, the use of nozzle mixing burners, and the 2-stage combustion in thermal oxidiser 30, combine to minimise overall energy consumption and therefore operating costs, greenhouse gas and NO_x emissions, and to increase throughput by minimising the gas volumes processed.

20 These features also allow maintenance of metal temperatures above 500°C to minimise dioxin formation from PCB or salt-contaminated soils, but below 700°C to minimise exchanger metal oxidation and corrosion. In addition, the system design allows control such that the heat exchanger exit gas temperature is maintained above 600°C to further minimise dioxin formation.

25 It is believed that, relative to no pre-heating, a total 55% reduction in energy consumption is achieved with the illustrated system by pre-heating all combustion air and the contaminant hydrocarbon vapours, at a level where combustion of hydrocarbon vapours in desorber kiln 20 is at about 20%. The reduction in energy consumption is complemented by reduced CO₂ and NO_x levels.

30 A further advantage of preheating is that the size of the thermal oxidiser in

particular, and to a lesser extent the kiln and the baghouse, can be reduced.

The drawing also illustrates several modules for further off-gas treatment downstream of heat exchanger 40. These modules may be variously provided according to the characteristics of the contamination. For low chlorine containing
5 soils, there is no further off-gas treatment and a short refractory line stack 60 is utilised. This approach minimises water and electrical energy consumption.

For high chlorine or PCB containing soils, where the risk of dioxin or hydrochloride containing gases is high, a scrubber section 62 is used to quench the off-gases and remove the chlorides. A preferred embodiment under these
10 conditions is to allow a small bleed of hot off-gas (about 10%, depending on contamination levels) to bypass the scrubber on line 63 to provide sufficient re-heating of the scrubbed gas stream in the stack to prevent drooping or visible fumes. A proportion of the pre-heated combustion air may also be delivered to this bypass 63 by a delivery duct 43c.

15 For gases of intermediate chlorine compound content, an ambient air quenching module is used, wherein a large volume of ambient air is injected at 65 into stack 60 to rapidly quench (within less than 750ms) the off-gases to below 200°C. Such a module might comprise, for example, a fan sucking in ambient air or an ejector powered by the hot offgases.

20 It will be understood that the invention disclosed and defined in this specification extends to all alternative combinations of two or more of the individual features mentioned or evident from the text or drawings. All of these different combinations constitute various alternative aspects of the invention.

CLAIMS

1. A process for remediating soil contaminated with hydrocarbons, including:

desorbing the hydrocarbon contaminants from a bed of the soil by thermal
desorption in a treated desorption chamber and thereafter combusting the
contaminants in a thermal oxidiser;

wherein combustion air for said desorption chamber and said thermal
oxidiser, and said desorbed contaminants prior to admission to said thermal
oxidiser, are preheated by heat exchange with offgases from the thermal
oxidiser.
2. A process according to claim 1, wherein said offgases preheat the
combustion air first and then the desorbed contaminants.
3. A process according to claim 1 or 2, wherein excess preheated air is vented
during treatment of higher contaminated soil.
4. A process according to any one of claims 1 to 3, wherein the heat
exchange is conducted in a heat exchanger having metal heat exchange surfaces
and wherein the metal surface temperatures are maintained above 500°C and
below 700°C.
5. A process according to claim 4, wherein the heat exchanger is arranged for
co-current flow.
6. A process according to any one of claims 1 to 5, wherein the hot gas flow
through both the combustion air and contaminants heat exchanges is controlled.
7. A process according to any one of claims 1 to 6, wherein the separated
contaminants are treated in said thermal oxidiser in at least two stages, including
a combustion stage in which the contaminants are combusted with a first supply of
combustion air at a substantially adiabatic temperature in the range 900 - 1200°C,

and a second stage in which a second supply of combustion air is admitted for combustion of residual compounds and for controlling the offgas outflow temperature.

8. A process according to any one of claims 1 to 7, wherein desorbed
5 contaminants in gaseous form are at least in part combusted within said desorption chamber by controlled admission of air into said chamber above said bed to effect such combustion.

9. Apparatus for remediating soil contaminated with hydrocarbons, including:

10 first furnace means defining a desorption chamber in which a bed of said soil may be treated to separate the hydrocarbon contaminants from the soil by thermal desorption;

second furnace means for combusting hydrocarbon contaminants by thermal oxidation;

15 means for conveying combustion air to said desorption chamber and to said second furnace means, and for conveying the desorbed contaminants from the absorption chamber to the second furnace means; and

heat exchange means arranged for preheating said combustion air and said desorbed contaminants by heat exchange with offgases from the second furnace means.

20 10. Apparatus according to claim 9, wherein the heat exchange means is arranged in a series configuration so that said offgases preheat the combustion air first and then the desorbed contaminants.

11. Apparatus according to claim 9 or 10, wherein the heat exchange means is
25 directly installed in the hot gas duct at the offgas outlet end of the second furnace means.

12. Apparatus according to claim 11, wherein the heat exchange means is arranged for co-current flow.

13. Apparatus according to claim 11 or 12, wherein the leading tube bank of the heat exchange means incorporates variable tube spacing to facilitate said direct
5 installation.

14. Apparatus according to any one of claims 9 to 13, further including an energy dump valve from the heat exchange means for venting of excess preheated air.

15. Apparatus according to any one of claims 9 to 14, wherein the heat
10 exchange means includes a hot gas by-pass duct and damper system in either or both the offgas duct or by-pass duct to control hot gas flow through both the combustion air and contaminants heat exchangers.

16. Apparatus according to claim 15, wherein the heat exchanger for the contaminants is adapted to be made reversible depending on operating
15 conditions.

17. Apparatus according to any one of claims 9 to 16, wherein said second furnace for thermal oxidation includes at least two stages including a combustion stage in which the contaminants are combusted with a first supply of combustion air at a substantially adiabatic temperature in the range 900 - 1200°C, and a
20 second stage in which a second supply of combustion air is admitted for combustion of residual compounds and for controlling the offgas outflow temperature.

18. Apparatus according to any one of claims 9 to 17, further including:

25 means for controlled admission of air into said desorption chamber above said bed to effect in the said chamber at least partial combustion of said desorbed contaminants in gaseous form; and

means for conveying the products of said at least partial combustion to said second furnace means for further combustion therein.

19. A process for remediating soil contaminated with hydrocarbons, including:

5 desorbing the hydrocarbon contaminants from a bed of the soil by thermal desorption in a treated desorption chamber and thereafter combusting the contaminants in a thermal oxidiser;

10 wherein the separated contaminants are treated in said thermal oxidiser in at least two stages, including a combustion stage in which the contaminants are combusted with a first supply of combustion air at a substantially adiabatic temperature in the range 900 - 1200°C, and a second stage in which a second supply of combustion air is admitted for combustion of residual compounds and for controlling the offgas outflow temperature.

15 20. A process according to claim 19, wherein in the first stage of the thermal oxidiser, preheated near stoichiometric amounts of combustion air, preheated dedusted desorber offgases, and auxiliary fuel are injected.

21. A process according to claim 20, wherein the fuel rate and preheat to this burner is arranged to give said adiabatic flame temperature of the mixture of 900-1200°C.

20 22. A process according to any one of claims 19 to 21, wherein in the second zone of the thermal oxidiser, cold or preheated combustion air is injected into the hot gas stream to provide additional mixing and oxygen for combustion of residual compounds, and to control the gas inlet temperature to the heat exchangers.

25 23. A process according to any one of claims 19-22, wherein desorbed contaminants in gaseous form are at least in part combusted within said desorption chamber by controlled admission of air into said chamber above said bed to effect such combustion.

24. Apparatus for remediating soil contaminated with hydrocarbons, including:

first furnace means defining a desorption chamber in which a bed of said soil may be treated to separate the hydrocarbon contaminants from the soil by thermal desorption;

5 second furnace means for combusting hydrocarbon contaminants by thermal oxidation;

wherein said second furnace for thermal oxidation includes at least two stages including a combustion stage in which the contaminants are combusted with a first supply of combustion air at a substantially adiabatic
10 temperature in the range 900 - 1200°C, and a second stage in which a second supply of combustion air is admitted for combustion of residual compounds and for controlling the offgas outflow temperature.

25. Apparatus according to claim 24, further including, in the first stage of the thermal oxidiser, means to inject preheated near stoichiometric amounts of
15 combustion air, preheated dedusted desorber offgases, and auxiliary fuel.

26. Apparatus according to claim 25, wherein the means to inject is a nozzle mix burner.

27. Apparatus according to claim 26, wherein the fuel rate and preheat to the burner is arranged to give said adiabatic flame temperature of the mixture of 900-
20 1200°C.

28. Apparatus according to any one of claims 24 to 27, further including:

means for controlled admission of air into said desorption chamber above said bed to effect in the said chamber at least partial combustion of said desorbed contaminants in gaseous form; and

25 means for conveying the products of said at least partial combustion to said

second furnace means for further combustion therein.

29. A process for remediating soil contaminated with hydrocarbons, including:

5 desorbing the hydrocarbon contaminants from a bed of the soil by thermal desorption in a treated desorption chamber and thereafter combusting the contaminants in a thermal oxidiser,

wherein desorbed contaminants in gaseous form are at least in part combusted within said desorption chamber by controlled admission of air into said chamber above said bed to effect such combustion.

10 30. A process according to claim 29, wherein the desorption chamber is provided in a rotary kiln.

31. A process according to claim 30, wherein the rotary kiln is inclined.

15 32. A process according to claim 30 or 31, including admitting the contaminated soil to an upper, cooler end of the rotary kiln at a controlled rate and wherein rotation of the kiln causes the soil to move down the inside of the kiln towards the hotter end containing a burner.

33. A process according to any one of claims 29 to 32, wherein the at least partial combustion of the contaminants in the desorption chamber occurs both in close proximity to the soil bed and in the hot gas stream passing along the desorption chamber.

20 34. A process according to any one of claims 29 to 33, including injecting air at the burner end of the desorption chamber.

35. Apparatus for remediating soil contaminated with hydrocarbons, including:

25 first furnace means defining a desorption chamber in which a bed of said soil may be treated to separate the hydrocarbon contaminants from the soil by thermal desorption;

second furnace means for combusting hydrocarbon contaminants by thermal oxidation;

means for controlled admission of air into said desorption chamber above said bed to effect in the said chamber at least partial combustion of said desorbed contaminants in gaseous form; and

means for conveying the products of said at least partial combustion to said second furnace means for further combustion therein.

36. Apparatus according to claim 35, wherein, the desorption chamber is provided in a rotary kiln that thereby constitutes the first furnace means.

10 37. Apparatus according to claim 36, wherein the rotary kiln is inclined.

38. Apparatus according to any one of the claims 35 to 37, wherein the first furnace means is a high velocity desorber burner which provides a highly collimated stream of high temperature gases along the centre of the desorber.

15 39. A process according to any one of claims 1 to 8, 19 to 23, 29 to 34, wherein the offgas from thermal oxidation is further treated by one or more modular off-gas treatments.

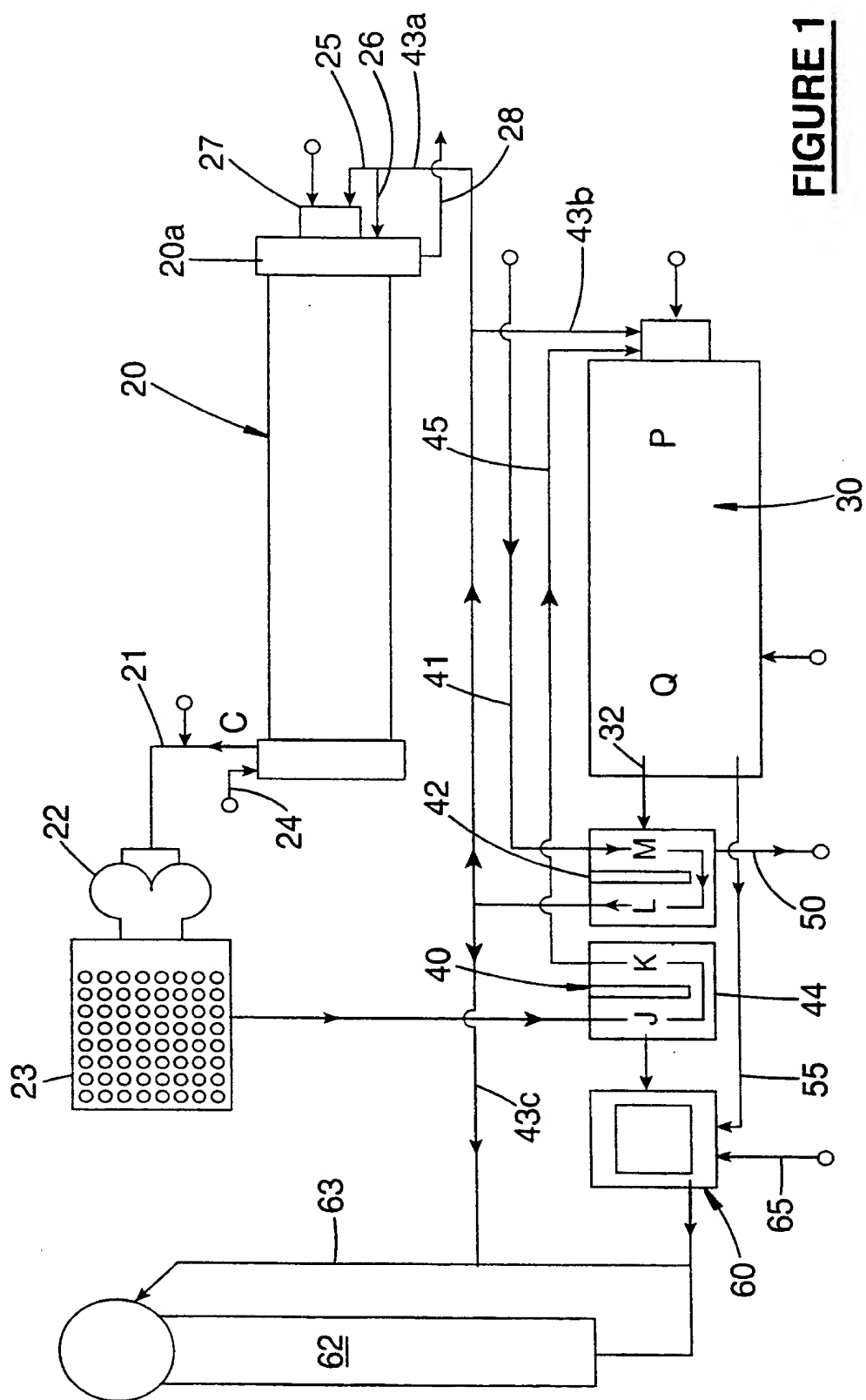


FIGURE 1

2 / 2

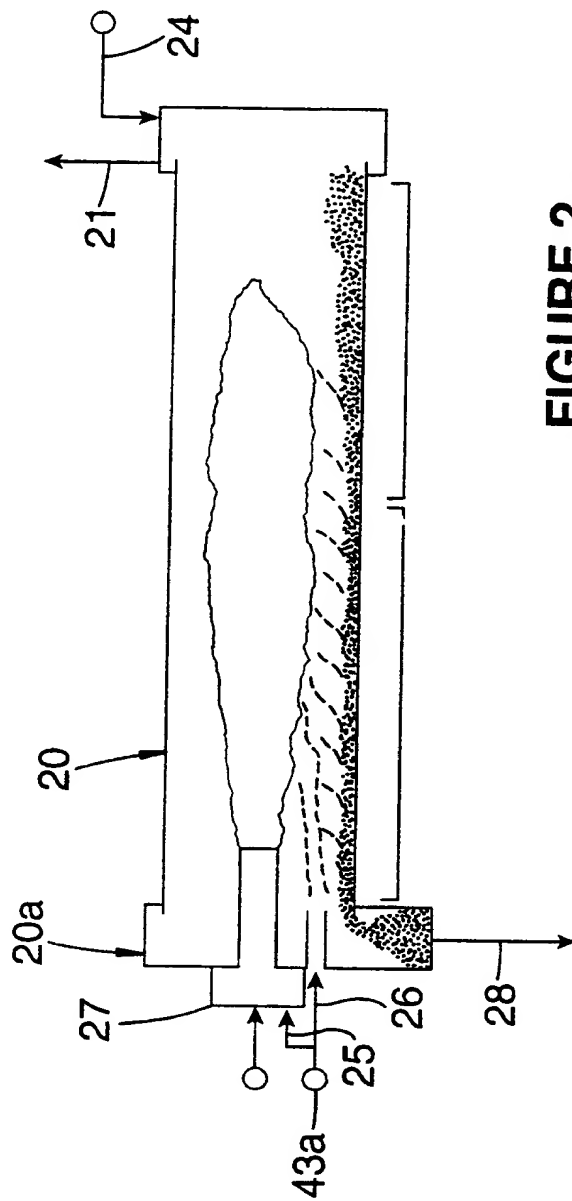


FIGURE 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU 99/00785

A. CLASSIFICATION OF SUBJECT MATTER

Int Cl⁶: B09C 1/06, F23G 7/14

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B09B, B09C 1/06, F23G 5/02, 5/027, 5/08, 7/00, 7/14, A62D 3/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU: B09C 1/06, F23G 7/14

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
WPAT AND JAPIO: IPC as above and keywords

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5 164 158 A (BRASHEARS et. al.) 17 November 1992 claim 1	1-28
Y	US 5 228 804 A (BALCH) 20 July 1993 abstract	1-28
Y	EP 155 022 A (ECOTECHNIEK) 18 September 1985 claim 1, page 1 line 1 to page 3 line 23	1-28

☒ Further documents are listed in the
continuation of Box C

☒ See patent family annex

* Special categories of cited documents:

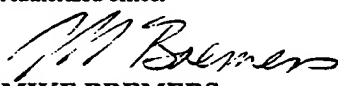
"A" Document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search
17 November 1999

Date of mailing of the international search report
26 NOV 1999

Name and mailing address of the ISA/AU
AUSTRALIAN PATENT OFFICE
PO BOX 200
WODEN ACT 2606 AUSTRALIA
E-mail address: pct@ipaustalia.gov.au
Facsimile No.: (02) 6285 3929

Authorized officer

MIKE BREMERS
Telephone No.: (02) 6283 2052

INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU 99/00785

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	DE 3 447 079 A (STILL) 6 March 1986 Derwent Abstract Accession No. 86-070201/11 Derwent Abstract.	29-39 8, 18, 28
Y	US 5 596 935 A (SWANSON) 28 January 1997 abstract, column 5 line 50-column 6 line 46	7, 17, 19-28
X Y	US 4 970 971 A (WILLIAMS) 20 November 1990 claims 1-3 claims 1-3	19-27 7, 17, 28

INTERNATIONAL SEARCH REPORT

International Application No.

PCT/AU 99/00785

Box I Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

Box II Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:
See Extra Sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU 99/00785

Box II

The international application does not comply with the requirements of unity of invention because it does not relate to one invention or to a group of inventions so linked as to form a single general inventive concept. In coming to this conclusion the International Searching Authority has found that there are different inventions as follows:

1. Independent claims 1 and 9 are directed to a process and apparatus for remediating soil wherein the contaminants are thermally desorbed then combusted in a thermal oxidiser wherein combustion air and desorbed contaminants are preheated by heat exchange with the offgases of the thermal oxidiser. It is considered that combustion air and desorbed contaminants are by heat exchange with the offgases of the thermal oxidiser comprises a first "special technical feature".
2. Independent claims 19 and 24 define a process and apparatus for remediating soil wherein the contaminants are thermally desorbed then combusted in a thermal oxidiser wherein the separated contaminants are treated in the thermal oxidiser in at least two stages. It is considered that contaminants in the thermal oxidiser in at least two stages comprises a second "special technical feature".
3. Independent claims 29 and 35 define a process and apparatus for remediating soil wherein the contaminants are thermally desorbed then combusted in a thermal oxidiser wherein the desorbed contaminants are at least in part combusted within said desorption chamber. It is considered that contaminants in the desorption chamber comprises a second "special technical feature".

These groups are not so linked as to form a single general inventive concept, that is, they do not have any common inventive features, which define a contribution over the prior art. The common concept linking together these groups of claims is a process and apparatus for remediating soil wherein the contaminants are thermally desorbed then combusted in a thermal oxidiser. However this concept is not novel in the light of:

US 4 974 528 A (BARCELL) 4 December 1990 see claim 1
US 5 378 083 A (SWANSON) 3 January 1995 see claim 3 and column 3 lines 55 - column 4 line 29
DE 3 447 079 A (STILL) 6 March 1986 see the Derwent abstract
US 4 815 398 A (KEATING) 28 March 1989 see the Derwent Abstract
WO 94/15150 A (ROBERTSON) 7 July 1994 see the abstract
WO 92/10215 A (GENCOR) 25 June 1992 see the attached abstract

Therefore these claims lack unity a posteriori.

Although these inventions share the same classification under the IPC there is significant effort involved in searching the second and third inventions together with the first invention since different search terms would be required. However, the second and third inventions (claims 19-39) could be searched together without significant extra effort for one additional fee.

Information on patent family members

PCT/AU 99/00785

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member	
US	5 164 158	AU	90516/91
		CA	2 097 588
		EP	561 906
		WO	92/10215
US	5 228 804	NONE	
EP	155 022	NL	84/00652
DE	3 447 079	NONE	
US	5 596 935	NONE	
US	4 970 971	CA	2 027 073
		JP	3 204 508

END OF ANNEX

REC'D 16 FEB 2001

WIPO

PCT

14

Applicant's or agent's file reference 40137588	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416).
International Application No. PCT/AU99/00785	International Filing Date (day/month/year) 16 September 1999	Priority Date (day/month/year) 28 September 1998
International Patent Classification (IPC) or national classification and IPC Int. Cl. ⁷ B09C 1/06, F23G 7/14		
Applicant INNOVA SOIL TECHNOLOGY PTY LTD et al		

- This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.
- This REPORT consists of a total of 5 sheets, including this cover sheet.
☒ This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

These annexes consist of a total of 9 sheet(s).

- This report contains indications relating to the following items:

- | | | |
|------|-------------------------------------|---|
| I | <input checked="" type="checkbox"/> | Basis of the report |
| II | <input type="checkbox"/> | Priority |
| III | <input type="checkbox"/> | Non-establishment of opinion with regard to novelty, inventive step and industrial applicability |
| IV | <input checked="" type="checkbox"/> | Lack of unity of invention |
| V | <input checked="" type="checkbox"/> | Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement |
| VI | <input type="checkbox"/> | Certain documents cited |
| VII | <input type="checkbox"/> | Certain defects in the international application |
| VIII | <input type="checkbox"/> | Certain observations on the international application |

Date of submission of the demand 18 April 2000	Date of completion of the report 23 January 2001
Name and mailing address of the IPEA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaaustralia.gov.au Facsimile No. (02) 6285 3929	Authorized Officer M. BREMERS Telephone No. (02) 6283 2052

I. Basis of the report

1. With regard to the elements of the international application:*

- ☐ the international application as originally filed.
- ☒ the description, pages 1-3, 10-13 as originally filed,
pages , filed with the demand,
pages 4-9 received on 17 November 2000 with the letter of 17 November 2000
- ☒ the claims, pages 14-16 as originally filed,
pages , as amended (together with any statement) under Article 19,
pages , filed with the demand,
pages 17-19 received on 17 November 2000 with the letter of 17 November 2000
- ☒ the drawings, pages 1, 2 as originally filed,
pages , filed with the demand,
pages , received on with the letter of
- ☐ the sequence listing part of the description:
pages , as originally filed
pages , filed with the demand
pages , received on with the letter of

2. With regard to the language, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language which is:

- ☐ the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).
- ☐ the language of publication of the international application (under Rule 48.3(b)).
- ☐ the language of the translation furnished for the purposes of international preliminary examination (under Rules 55.2 and/or 55.3).

3. With regard to any nucleotide and/or amino acid sequence disclosed in the international application, was on the basis of the sequence listing:

- ☐ contained in the international application in written form.
- ☐ filed together with the international application in computer readable form.
- ☐ furnished subsequently to this Authority in written form.
- ☐ furnished subsequently to this Authority in computer readable form.
- ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

4. ☐ The amendments have resulted in the cancellation of:

- ☐ the description, pages
- ☐ the claims, Nos.
- ☐ the drawings, sheets/fig.

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).**

* Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).

** Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report

IV. Lack of unity of invention

1. In response to the invitation to restrict or pay additional fees the applicant has:

- ☐ restricted the claims.
- ☐ paid additional fees.
- ☐ paid additional fees under protest.
- ☐ neither restricted nor paid additional fees.

2. ☐ This Authority found that the requirement of unity of invention is not complied with and chose, according to Rule 68.1, not to invite the applicant to restrict or pay additional fees.

3. This Authority considers that the requirement of unity of invention in accordance with Rules 13.1, 13.2 and 13.3 is

- ☐ complied with.
- ☒ not complied with for the following reasons:

The international application does not comply with the requirements of unity of invention because it does not relate to one invention or to a group of inventions so linked as to form a single general inventive concept. In coming to this conclusion the International Searching Authority has found that there are different inventions as follows:

1. Independent claims 1 and 9 are directed to a process and apparatus for remediating soil wherein the contaminants are thermally desorbed then combusted in a thermal oxidiser wherein combustion air and desorbed contaminants are preheated by heat exchange with the offgases of the thermal oxidiser. It is considered that combustion air and desorbed contaminants are by heat exchange with the offgases of the thermal oxidiser comprises a first "special technical feature".

2. Independent claims 19 and 29 define a process and apparatus for remediating soil wherein the contaminants are thermally desorbed then combusted in a thermal oxidiser wherein the desorbed contaminants are at least in part combusted within said desorption chamber and then the contaminants are treated in the thermal oxidiser in at least two stages. It is considered that the partial combustion and then the treatment of the contaminants in the thermal oxidiser in at least two stages comprises a second "special technical feature".

Continued in Supplemental Box

4. Consequently, the following parts of the international application were the subject of international preliminary examination in establishing this report:

- ☒ all parts.
- ☐ the parts relating to claims Nos.

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**1. Statement**

Novelty (N)	Claims 1-35	YES
	Claims	NO
Inventive step (IS)	Claims	YES
	Claims 1-35	NO
Industrial applicability (IA)	Claims 1-35	YES
	Claims	NO

2. Citations and explanations (Rule 70.7)

D1: US 5164158 A (BRASHEARS et. al.) 17 November 1992 claim 1

D2: US 5228804 A (BALCH) 20 July 1993 abstract

D3: EP 155022 A (ECOTECNIEK) 18 September 1985 claim 1 and page 1 line 1 to page 3 line 23

D4: DE 3447079 A (STILL) 6 March 1986 see the Derwent abstract

D5: US 5596935 A (SWANSON) 28 January 1997 abstract, column 5 line 50-column 6 line 46

D6: US 4970971 A (WILLIAMS) 20 November 1990 claims 1-3

Claims 1-18

D1 discloses a soil remediation unit wherein the clean exhaust gas of the thermal oxidiser is passed through a heat exchanger to heat the gaseous desorbed contaminants before entering the thermal oxidiser. D3 discloses a soil remediation system wherein the contaminants have been desorbed and combusted and the combustion gases are used in heat exchange relationship to preheat the combustion air. See claim 1 line 7.

The problem that the applicant is attempting to solve is to provide a soil remediation system wherein energy usage is optimised (page 4 lines 12-18). This is the same problem that D1 (see column 1 lines 45-50) and D3 (see page 2 lines 10-18). It is considered that a person skilled in the art searching for a solution to this problem would have found both documents D1 and D3 and considered them relevant to the problem.

It is considered to be obvious to combine the teachings of D1 and D3 in order to develop a system wherein the hot exhaust gases are used to preheat both the incoming air and the gaseous desorbed contaminants. Consequently claims 1 and 9 are not inventive. The features added by claims 2-8 and 10-18 are features which cannot be considered to involve an inventive step.

Claims 19-35

D4 discloses the partial combustion of the contaminants in the desorption chamber. D6 discloses a system for processing waste material wherein the waste is classified to produce fine residue and vaporizable substances using heat from a combustion step to promote vaporization. The fine residue and vaporizable substances are then subjected to a three stage combustion step. Combustion takes place at about 2000 degrees F (about 1100 degrees C) and combustion air is supplied at each of the combustion stages.

It is considered that it would be obvious to combine the teachings of D4 and D6 to develop the process and apparatus as defined in claims 19 and 29. Therefore claims 19 and 29 are not inventive. The features defined in claims 20-28 and 30-35 are either disclosed in D4 and/or D6 or are features that cannot be considered to involve an inventive step.

Supplemental Box

(To be used when the space in any of the preceding boxes is not sufficient)

Continuation of Box IV

These groups are not so linked as to form a single general inventive concept, that is, they do not have any common inventive features, which define a contribution over the prior art. The common concept linking together these groups of claims is a process and apparatus for remediating soil wherein the contaminants are thermally desorbed then combusted in a thermal oxidiser. However this concept is not novel in the light of:

US 4 974 528 A (BARCELL) 4 December 1990 see claim 1

US 5 378 083 A (SWANSON) 3 January 1995 see claim 3 and column 3 lines 55 - column 4 line 29

DE 3 447 079 A (STILL) 6 March 1986 see the Derwent abstract

US 4 815 398 A (KEATING) 28 March 1989 see the Derwent Abstract

WO 94/15150 A (ROBERTSON) 7 July 1994 see the abstract

WO 92/10215 A (GENCOR) 25 June 1992 see the abstract

Therefore these claims lack unity a posteriori.

Remediation plants may be either stationary or mobile, with the larger, stationary plants being restricted to remediation of large heavily contaminated sites (eg large integrated steelworks sites), regional clusters of contaminated sites, or under circumstances where transport of contaminated materials is economic
5 and not hazardous.

Key technical factors in thermal remediation include:

- Solids temperature and contact time.
- Soil moisture when treated.
- Actual soil hydrocarbon contaminants present.
- 10 • Other contamination, eg chlorine compounds and heavy metals.
- Extraneous rubble.

It is an object of the present invention to provide an improved method and apparatus for remediating soil contaminated with hydrocarbons that is capable in preferred embodiment of optimising energy usage and operating costs for a given
15 soil throughput, and that is preferably adaptable to treat short chain, long chain, aromatic, and polychlorinated hydrocarbons. In particular embodiments, it is further desired to minimise environmental impacts, especially greenhouse gases, NO_x and dioxin/furan emissions.

Summary of Invention

20 The invention accordingly provides, in a first aspect, a process for remediating soil contaminated with hydrocarbons, including:

desorbing the hydrocarbon contaminants from a bed of the soil by thermal desorption in a treated desorption chamber and thereafter combusting the contaminants in a thermal oxidiser;

25 wherein combustion air for said desorption chamber and said thermal oxidiser, and said desorbed contaminants prior to admission to said thermal

oxidiser, are preheated by heat exchange with offgases from the thermal oxidiser.

The invention further provides, in its first aspect, apparatus for remediating soil contaminated with hydrocarbons, including:

5 first furnace means defining a desorption chamber in which a bed of said soil may be treated to separate the hydrocarbon contaminants from the soil by thermal desorption;

second furnace means for combusting hydrocarbon contaminants by thermal oxidation;

10 means for conveying combustion air to said desorption chamber and to said second furnace means, and for conveying the desorbed contaminants from the absorption chamber to the second furnace means; and

heat exchange means arranged for preheating said combustion air and said desorbed contaminants by heat exchange with offgases from the second
15 furnace means.

Preferably, the heat exchange means is further arranged in a series configuration so that said offgases preheat the combustion air first and then the desorbed contaminants.

Advantageously, the heat exchange means is directly installed in the hot
20 gas duct at the offgas outlet end of the second furnace means for thermal oxidation, and is preferably arranged for co-current flow. The leading tube bank of the heat exchange means preferably incorporates variable tube spacing to facilitate the aforementioned direct installation (preferably without radiation shields or excess metal temperatures).

25 There may be an energy dump valve from the heat exchange means for venting of excess preheated air as will occur during treatment of higher

contaminated soil. Preferably, the process and energy dump valve are controlled to maintain metal temperatures above 500°C, to minimise dioxin formation from PCB or salt contaminated soils, but below 700°C to minimise metal oxidation, corrosion and expansion damage. The heat exchange means may have a hot gas
5 by-pass duct and damper system in either or both the offgas duct or by-pass duct to control hot gas flow through both the combustion air and contaminants heat exchanges.

The heat exchanger for the contaminants may have either co-current or counter current flow, and may be adapted to be made reversible depending on
10 operating conditions.

In a second aspect, the invention provides a process for remediating soil contaminated with hydrocarbons, including:

desorbing the hydrocarbon contaminants from a bed of the soil by thermal desorption in a treated desorption chamber and thereafter combusting the
15 contaminants in a thermal oxidiser,

combusting the desorbed contaminants at least in part within said desorption chamber by controlled admission of air into said chamber above said bed to effect such combustion;

wherein the separated contaminants are treated in said thermal oxidiser in
20 at least two stages, including a combustion stage in which the contaminants are combusted with a first supply of combustion air at a substantially adiabatic temperature in the range 900 - 1200°C, and a second stage in which a second supply of combustion air is admitted for combustion of residual compounds and for controlling the offgas outflow temperature.

25 In its second aspect, the invention further provides apparatus for remediating soil contaminated with hydrocarbons, including:

first furnace means defining a desorption chamber in which a bed of said

soil may be treated to separate the hydrocarbon contaminants from the soil by thermal desorption;

second furnace means for combusting hydrocarbon contaminants by thermal oxidation;

5 means for controlled admission of air into said desorption chamber above said bed to effect in the said chamber at least partial combustion of said desorbed contaminants in gaseous form;

means for conveying the products of said at least partial combustion to said second furnace means for further combustion therein; and

10 wherein said second furnace for thermal oxidation includes at least two stages including a combustion stage in which the contaminants are combusted with a first supply of combustion air at a substantially adiabatic temperature in the range 900 - 1200°C, and a second stage in which a
15 second supply of combustion air is admitted for combustion of residual compounds and for controlling the offgas outflow temperature.

Preferably, the desorption chamber is provided in a rotary kiln that thereby constitutes the first furnace means and is preferably inclined. The contaminated soil, which is advantageously optimally sized and prepared, is preferably admitted to an upper, cooler end of the rotary kiln at a controlled rate, and the rotation of
20 the kiln then causes the soil to move down the inside of the kiln towards the hotter end containing a burner. The heat from the burner and other exothermic reactions in the kiln heats the soil, causing it to dry and "desorb" (a term which includes without limitation evaporation, decomposition and gasification) contained hydrocarbon contaminants.

25 Preferably, the at least partial combustion of the contaminants in the desorption chamber occurs both in close proximity to the soil bed and in the hot gas stream passing along the desorber. The air admitted to effect such combustion may be injected at the burner end of the desorption chamber. The first

furnace means is preferably a high velocity desorber burner which provides a highly collimated stream of high temperature gases along the centre of the desorber.

In the preferred operation of the first stage of the thermal oxidiser, 5 preheated near stoichiometric amounts of combustion air, preheated dedusted desorber offgases, ie desorbed contaminants, and auxiliary fuel are injected, preferably via a nozzle mix burner. The fuel rate and preheat to this burner is arranged to give said adiabatic flame temperature of the mixture of 900-1200°C, and thus avoids localised high temperatures and high NO_x from the use of 10 preheated combustion air. However, the temperature is sufficient to destroy any gaseous contaminants in the desorber gases. These hot gases then pass into the second zone of the thermal oxidiser where cold or preheated combustion air is injected into the hot gas stream to provide additional mixing and oxygen for combustion of residual compounds, and to control the gas inlet temperature to the 15 heat exchangers.

The invention also extends to methods or apparatus incorporating both of the aspects of the invention.

The offgas from thermal oxidation may be further treated (eg after said heat exchanges in the first aspect of the invention) by one or more modular off-gas 20 treatments according to the nature of the original contaminants, and the requirements of the soils being remediated. For low chlorine containing soils, such an off-gas treatment system may be omitted, and replaced with a short stack. For higher chlorine containing soils, where the risk of dioxin or hydrochloride containing gases is evident, a scrubber section may be used. A suitable scrubber 25 can treat most of the offgases. A small bleed of hot off-gas or preheated combustion air is allowed to by-pass the scrubber to provide reheating of the scrubbed gas stream in the stack thereby preventing drooping or visible plumes. For gases of intermediate chlorine compound content, a module comprising an ambient air quenching module may be used, wherein a large volume of ambient 30 air is injected into the offgases to rapidly quench them to less than 200°C.

Brief Description of the Drawings

Figure 1 is a block flow diagram of an apparatus incorporating embodiments of the principal aspects of the invention; and

Figure 2 is a diagram depicting combustion of desorbed contaminants in
5 the desorber kiln.

Description of Preferred Embodiments

The illustrated system includes a pair of furnaces 20, 30, being a slightly inclined countercurrent rotary kiln 20 for effecting thermal desorption and a 2-stage thermal oxidiser 30. The off-gases 32 from thermal oxidiser 30 pass directly
10 through a 2-stage heat exchanger 40. In the first stage 42 of the series arrangement, itself consisting of a pair of sub-stage tube banks M, L, cold combustion air admitted along supply duct 41 is pre-heated for delivery to the lower, burner ends of desorber kiln 20 and oxidiser 30 by respective combustion

means for conveying the products of said at least partial combustion to said second furnace means for further combustion therein.

* 19. A process for remediating soil contaminated with hydrocarbons, including:

5 desorbing the hydrocarbon contaminants from a bed of the soil by thermal desorption in a treated desorption chamber and thereafter combusting the contaminants in a thermal oxidiser;

combusting the desorbed contaminants at least in part within said desorption chamber by controlled admission of air into said chamber above said bed to effect such combustion;

10 wherein the separated contaminants are treated in said thermal oxidiser in at least two stages, including a combustion stage in which the contaminants are combusted with a first supply of combustion air at a substantially adiabatic temperature in the range 900 - 1200°C, and a second stage in which a second supply of combustion air is admitted for combustion of
15 residual compounds and for controlling the offgas outflow temperature.

20. A process according to claim 19, wherein the desorption chamber is provided in a rotary kiln.

21. A process according to claim 20, wherein the rotary kiln is inclined.

22. A process according to claim 20 or 21, including admitting the contaminated
20 soil to an upper, cooler end of the rotary kiln at a controlled rate and wherein rotation of the kiln causes the soil to move down the inside of the kiln towards the hotter end containing a burner.

23. A process according to any one of claims 19 to 22, wherein the at least partial combustion of the contaminants in the desorption chamber occurs both in
25 close proximity to the soil bed and in the hot gas stream passing along the desorption chamber.

24. A process according to any one of claims 19 to 23, including injecting air at the burner end of the desorption chamber.
25. A process according to any one of claims 19 to 24, wherein in the first stage of the thermal oxidiser, preheated near stoichiometric amounts of combustion air, preheated dedusted desorber offgases, and auxiliary fuel are injected.
26. A process according to claim 25, wherein the fuel rate and preheat to this burner is arranged to give said adiabatic flame temperature of the mixture of 900-1200°C.
27. A process according to any one of claims 19 to 26, wherein in the second zone of the thermal oxidiser, cold or preheated combustion air is injected into the hot gas stream to provide additional mixing and oxygen for combustion of residual compounds, and to control the gas inlet temperature to the heat exchangers.
28. A process according to any one of claims 1 to 8, 19 to 27, wherein the offgas from thermal oxidation is further treated by one or more modular off-gas treatments.
- * 29. Apparatus for remediating soil contaminated with hydrocarbons, including:
- first furnace means defining a desorption chamber in which a bed of said soil may be treated to separate the hydrocarbon contaminants from the soil by thermal desorption;
- second furnace means for combusting hydrocarbon contaminants by thermal oxidation;
- means for controlled admission of air into said desorption chamber above said bed to effect in the said chamber at least partial combustion of said desorbed contaminants in gaseous form;
- means for conveying the products of said at least partial combustion to said

second furnace means for further combustion therein;

5 wherein said second furnace for thermal oxidation includes at least two stages including a combustion stage in which the contaminants are combusted with a first supply of combustion air at a substantially adiabatic temperature in the range 900 - 1200°C, and a second stage in which a second supply of combustion air is admitted for combustion of residual compounds and for controlling the offgas outflow temperature.

30. Apparatus according to claim 29, wherein, the desorption chamber is provided in a rotary kiln that thereby constitutes the first furnace means.
- 10 31. Apparatus according to claim 30, wherein the rotary kiln is inclined.
32. Apparatus according to any one of the claims 29 to 31, wherein the first furnace means is a high velocity desorber burner which provides a highly collimated stream of high temperature gases along the centre of the desorber.
- 15 33. Apparatus according to any one of claims 29-32, further including, in the first stage of the thermal oxidiser, means to inject preheated near stoichiometric amounts of combustion air, preheated dedusted desorber offgases, and auxiliary fuel.
34. Apparatus according to claim 33, wherein the means to inject is a nozzle mix burner.
- 20 35. Apparatus according to claim 34, wherein the fuel rate and preheat to the burner is arranged to give said adiabatic flame temperature of the mixture of 900-1200°C.